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The proposed decision analysis solution technique provides a feasible method to maximize the utility of organizing artillery for combat based on an operational posture perception provided by the J-STOCHWAR. The influence diagram algorithm incorporates the effects and weights of the five fundamentals involved in the organization process. The methodology provides accurate input to J-STOCHWAR that approximates real world results.

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MODELING CORPS ARTILLERY IN A THEATER LEVEL COMBAT MODEL

THESIS

Richard F. Bowyer, Captain, USA

AFIT/GOR/ENS/95M-03

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MODELING CORPS ARTILLERY IN A THEATER LEVEL COMBAT MODEL

THESIS

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Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science Operations Research

Richard F. Bowyer, B.S.

Captain, USA

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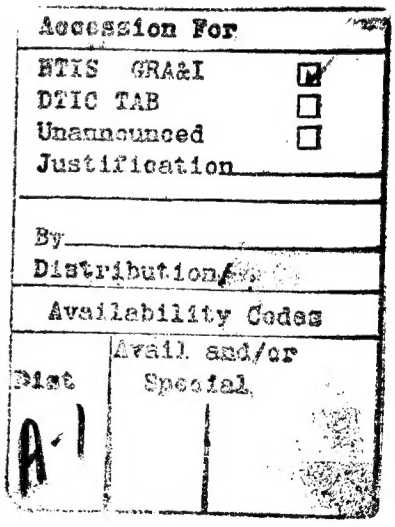

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Richard F. Bowyer

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ABSTRACT

This thesis describes the development of a methodology to explicitly model corps artillery assets in the Joint Staff's Joint Stochastic Warfare Research (J-STOCHWAR) and to quantify Army doctrine that guides organization of artillery for combat. The methodology incorporates corps artillery into the J-STOCHWAR by using the five fundamentals for organizing for combat, which reflect Army doctrine, and combines them with basic concepts already used in existing theater-level models. Other aspects of the problem include determining the appropriate level of detail, identifying techniques to solve the problem, and verifying the results.

The proposed decision analysis solution technique provides a feasible method to maximize the utility of organizing artillery for combat based on an operational posture perception provided by the J-STOCHWAR. The influence diagram algorithm incorporates the effects and weights of the five fundamentals involved in the organization process. As such, the methodology provides accurate input to the J-STOCHWAR which approximates real world results.

MODELING CORPS ARTILLERY IN A THEATER LEVEL COMBAT MODEL

I. INTRODUCTION

1.1 Purpose and Background

The purpose of this thesis is to develop the decision logic to explicitly model corps artillery in the Joint Stochastic Analysis Research (J-STOCHWAR). It also serves as a decision support system to quantify Army doctrine for task organizing artillery for combat.

The J-STOCHWAR is a research effort to develop a theater-level analysis capability that explicitly handles variability and uncertainty in an aggregated theater representation for varying force structures (9:1, 10:6, 21:1). The research is being conducted at the Air Force Institute of Technology and the Naval Postgraduate School with the support and sponsorship of the Force Structure, Resource and Assessment Directorate (J-8) of The Joint Staff.

1.1.1 Model Purpose. The Joint Stochastic Analysis Research is an analytical air-ground simulation model of the employment of forces in global contingencies. As such, decision makers can use the J-STOCHWAR as a tool to analyze the outcomes of their decisions in a theater-level campaign. The model also analyzes measures of effectiveness (MOEs) at critical events and the outcomes of major sequences of events in each simulation run. Additionally, the J-STOCHWAR will answer questions concerning force structure, affects of equipment and systems, and campaign planning (15:13-14).

1.1.2 Model Qualities. The qualities dimension of a combat model is the specific entities and processes that the model attempts to represent. The specific qualities of a

combat model as outlined in *A Taxonomy for Warfare Simulation* are categorized in the following areas: domain, span, environment, force composition, scope of conflict, and level of detail (16).

Domain. Currently, the domain for the J-STOCHWAR is land and air. However, future enhancements to the J-STOCHWAR will incorporate the sea domain.

Span. The span of a model is the scale of the domain. In the J-STOCHWAR the span is to accommodate any theater of operation or major regional contingency (MRC) given a data base for the specific area of operations. The current span supports a prototype database of the Korean peninsula.

Environment. All movements of ground and air units in the J-STOCHWAR occur on two distinct arc-node networks: a ground and an air network. Currently, the J-STOCHWAR includes two databases. The first database contains a 16-node network, and the second database contains a 64-node network.

The network consists of two types of nodes: physical and transit. A physical node is located at the intersection of an avenue of approach and a line of communication. Additionally, physical nodes are spotted at geographic points of interest; key terrain; air bases; logistical bases; probable and actual defensive positions; and terrain oriented objectives (15:25, 22:1). The arcs that connect the physical nodes retain the same attributes as the corresponding terrain that lies between the node locations. Each arc contains four distinct attributes: distance between nodes, road classification, width of the mobility corridor, and terrain classification (15:25). The arcs are also referred to as transit nodes. The transit nodes that separate the physical nodes are not visually displayed on the

arc-node network, but are internal to the model design. In areas that have very dissimilar terrain, multiple transit nodes are used to account for the non-homogeneity between physical nodes (15:26).

A separate network is used for air movement, but it operates on principles similar to those described in the ground network. The air network contains an air grid system which is overlaid onto the theater of operations and divided into checkerboard type squares. The size of the squares varies according to the specific scenario, as the ground network varies with each specific theater of operation. The primary purpose for the air grid system is to facilitate selection of ingress and egress routes to and from targets (15:29).

The J-STOCHWAR does handle various types of terrain, ranging from flat to mountainous, and the existence of natural and/or man-made obstacles. The J-STOCHWAR does not model weather effects, except in the air mission planning algorithm.

Force Composition. The forces represented in the J-STOCHWAR consist of joint and combined forces for both RED and BLUE sides. A joint force consists of Army, Navy, Air Force, and Marine assets; whereas a combined force consists of allied assets. The basic unit size for each combatant is a maneuver brigade. The J-STOCHWAR also compensates for the asymmetric composition of each force. The model permits the definition of as many types of units as desired. Once the types of units are defined, then multiple physical units can be instantiated for each type.

Scope of Conflict. The category of weapons in the J-STOCHWAR is

conventional; however, future modifications will facilitate nuclear, biological, and chemical type weapons.

Level of Detail of Processes and Entities. As mentioned earlier, the lowest discrete entity modeled in the J-STOCHWAR is a maneuver brigade or equivalent. A maneuver brigade will vary in size depending on the types of organic weapon systems and is usually labeled as either light or heavy. A typical brigade will consist of between 1,500 to 2,000 personnel.

Some of the processes represented in the J-STOCHWAR include command, control, communication and intelligence (C3I), air strike, and attrition. Maneuver is predicated on perceptions of enemy operations and targets generated by the C3I module within the model. These perceptions also dictate the tactics for each side (9:1). For example, one side may decide to split its forces to attack the opposing force if the perception is that the opposing force is weaker.

One undeveloped process in the J-STOCHWAR is the decision logic to model corps artillery as an operational asset or entity (20:1-3, 21:2-3). Corps artillery is an important asset that affects the outcome of battle and needs to be modeled correctly. It is a separate combat multiplier and differs significantly from division level artillery assets.

1.1.3 Corps Artillery Organization. In combat operations, corps artillery consists of multiple field artillery (FA) brigades. Each corps will have one general support FA brigade; in addition, the corps artillery will have one reinforcing FA brigade for each of the corps' divisions (14:16). Figure 1-1 reflects one possible organization chart for corps artillery in which the maneuver corps contains two heavy divisions. Figure 1-2 depicts an

organization chart for corps artillery in support of an airborne, air assault, or light division. Each FA brigade may contain up to six field artillery battalions (5:4-1). The weapon systems found within the corps artillery may consist of the MLRS, the Army Tactical Missile System (ATACMS), the M109 series self-propelled howitzer, the M110A1 self-propelled howitzer, and 155-millimeter towed howitzers.[1] Additionally, the corps artillery contains the AN/TPQ-37 counter-battery radar (CBR) and the AN/TPQ-36 counter-mortar radar (CMR) for target acquisition. Each of these systems is vital for the corps artillery to carry out its many roles.

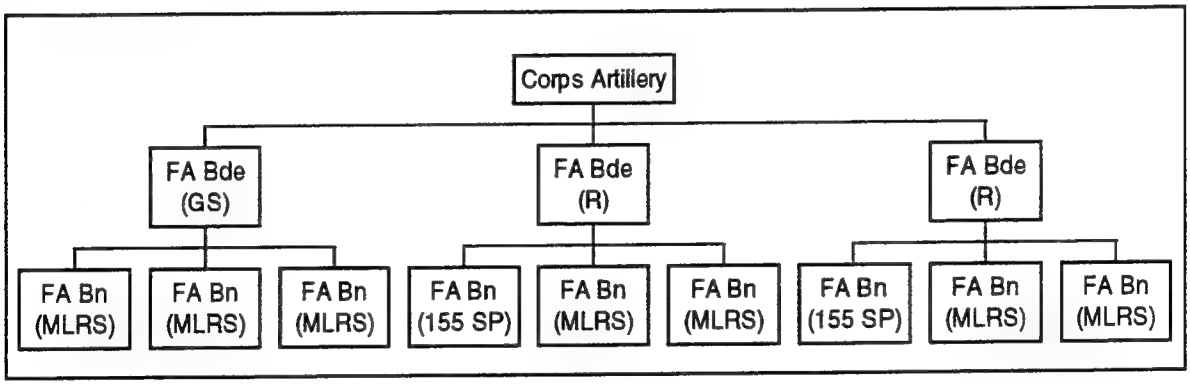


Figure 1-1 Corps Artillery Organization for a Heavy Maneuver Corps

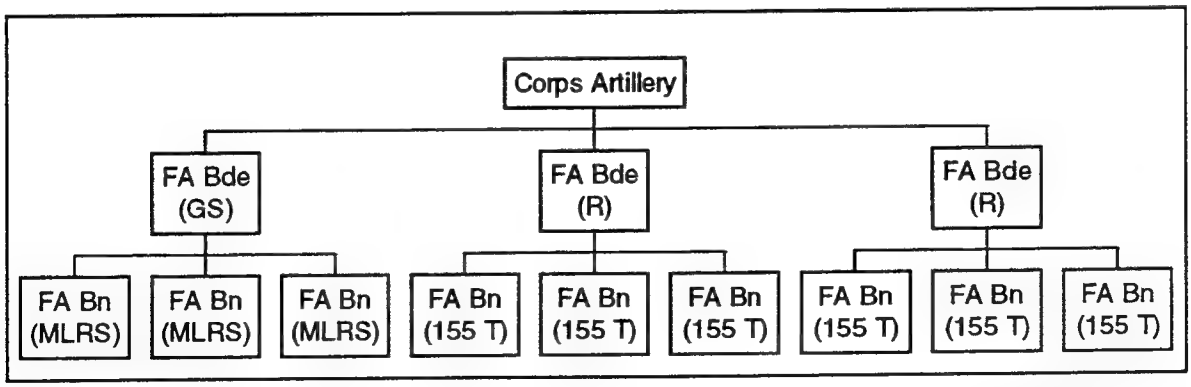


Figure 1-2 Corps Artillery Organization for a Light, Airborne or Air Assault Corps

[1] A detailed description of each weapon system is in Appendix B.

1.1.4 Roles of the Corps Artillery. The role of corps artillery is to provide close fire support for corps maneuver forces, counterfires, and interdiction fires (6:1-10-1-11). The purpose of these fires is to destroy, neutralize, or suppress enemy forces in accordance with the guidance of the maneuver commander.

Close support fires engage enemy forces and equipment that immediately threaten friendly forces in the attack or defense. The corps commander provides close support for his forces by assigning tactical missions to artillery units. By doctrine, all artillery units are assigned one of four tactical missions--General Support (GS), General Support-Reinforcing (GS-R), Reinforcing (R), or Direct Support (DS) (6:1-11-1-13). However, corps artillery units will usually only have a mission of GS, GS-R, or R. The DS mission is most often assigned to organic division artillery units and not to corps artillery assets. By assigning different missions, the corps commander has considerable flexibility in the employment of artillery as a combat multiplier. He has the ability to inflict damage far beyond the range of direct fire weapons.

In addition to close support fires, corps artillery also provides counterfire. Counterfire is normally the primary responsibility of the corps artillery. Counterfires specifically attack the enemy's indirect fire systems--mortars, artillery, air defense, missiles, and rockets. These fires are immediately responsive to the corps commander and allow him freedom of action to fight the close battle. Although counterfire is immediately responsive, it is not a separate artillery battle. Counterfire is planned and executed by corps artillery units for both offensive and defensive operations (6:1-10-1-11).

After counterfire, a secondary responsibility of the corps artillery is interdiction

fires. Interdiction fires attempt to disrupt, delay and destroy enemy forces that cannot fire their primary weapon systems on friendly forces due to range issues or restrictive terrain. Targeted forces would be enemy forces that are not fighting the direct battle, or those which are just arriving to the area of operations. The maneuver commander uses interdiction fires to enhance offensive maneuver capability (6:1-11). Because of the many roles that corps artillery can perform and because it affects the outcome of battle, it is a valuable operational asset in any theater of operations and should be modeled to account for its significance.

1.2 Scope of Research

1.2.1 Research Topics.

To develop the decision logic explicitly in the J-STOCHWAR, the research encompassed three primary areas: decision analysis techniques, theater-level combat models, and Army doctrine concerning the tactical considerations for the employment of corps artillery.

Decision analysis techniques provide the first research area for examination. These techniques are very beneficial in making decisions involving uncertainties and multiple objectives. One of the first problems in developing the decision logic to model corps artillery is organizing the artillery for combat given several influencing factors and uncertainties. The factors include: the mission and commander's concept, enemy targets and fire support capabilities, troops/fire support units available, terrain and weather conditions, and time available (METT-T). Incorrect assumptions about any of the factors could lead to terrible results. However, decision analysis provides the tools to deal with these factors.

Analysis of other theater-level combat models was the second area to be examined. The algorithms and decision logic developed in these models furnish additional insight for modeling corps artillery in the J-STOCHWAR. Although each model contains conceptual differences for dealing with corps artillery, they form a basis from which to begin development of the corps artillery mission selection algorithm. Additionally, the models provide a representation of the necessary level of resolution required to adequately model corps artillery.

The final research area was Army doctrine. For decision makers to gain any analysis or information from the J-STOCHWAR, the model must rely on the basic principle applied to any simulation: "For the purposes intended it needs to be like the real thing" (3:5). Thus, the doctrine used by Army decision makers to organize and position corps artillery in the "real" world must be reflected in the decision logic defined in the model. Decision makers might not accept a model which does not adhere to current doctrine.

1.2.2 Problem Definition. Representing the different tactical missions and positioning of artillery in a combat model is complex (1:2). All the major factors influencing the development of the decision logic to model corps artillery must be determined. In addition to the factors of METT-T, other factors include command relationship and the five guiding fundamentals for organizing field artillery for combat. Doctrinally, the fundamentals each have equal weight and are as follows (6:1-15-1-16):

1) Adequate field artillery support for committed combat units (close support fires)

2) Weight to the main attack in offense or most vulnerable area in defense (close support fires)

3) Facilitate future operations (interdiction fires)

4) Immediately available field artillery support for the commander to influence the action (counterfires)

5) Maximum feasible centralized control.

All of these factors must be considered to attempt to capture doctrine in this decision process. The influence diagram in Figure 1-3 depicts how the uncertainties associated with each of these factors affect the tactical mission assignment.

Another aspect of the problem definition was to determine if an existing theater-level model was suitable for use in the J-STOCHWAR. By analyzing and comparing the capabilities of existing combat models, it became clear that none of them doctrinally model the decision logic for the inclusion of corps artillery. Thus, a separate solution technique is necessary to model corps artillery for use in the J-STOCHWAR.

The overall problem definition can be stated as follows: *explicitly model corps artillery in the J-STOCHWAR by taking ideas from existing theater-level models, adding modifications that address each influencing factor, and reflecting Army doctrine.*

1.3 Overview

The following chapters contain the research, the proposed solution technique, results, and recommendations. Chapter 2 contains information on decision analysis techniques, information on other theater-level combat models, and a review of current Army doctrine pertaining to corps artillery. Chapter 3 discusses the proposed solution technique to model corps artillery in the J-STOCHWAR. The first section of Chapter 3 covers the decision logic and influence diagram to explicitly model the tactical mission assignment for corps artillery units. The second section defines the entities to be input

into the J-STOCHWAR as a direct result of the tactical mission determination in the first section. Chapter 4 contains the results and analysis from the solution technique, and Chapter 5 provides recommendations.

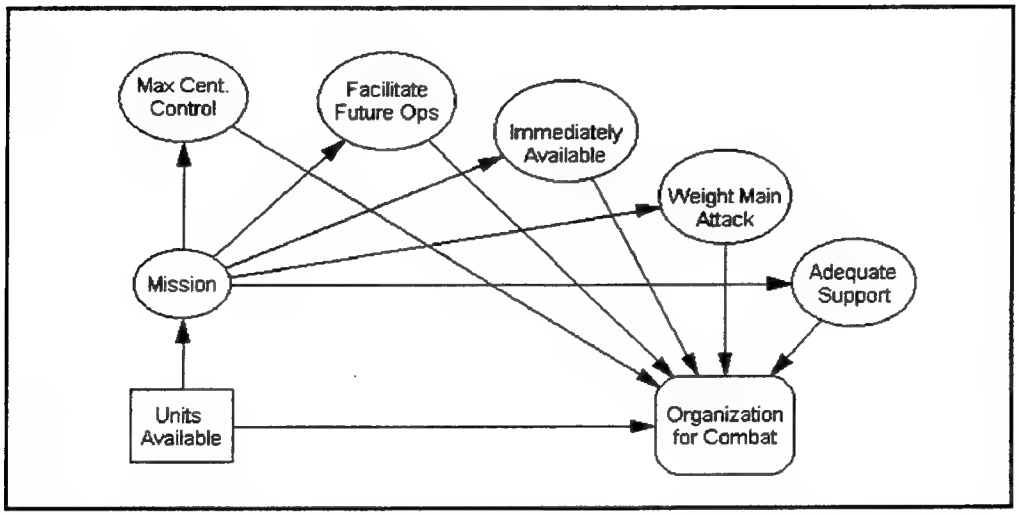


Figure 1-3 Influence Diagram Depicting Organization for Combat Process

II. DISCUSSION OF LITERATURE

2.1 Decision Analysis Techniques

Influence diagrams and decision trees are effective tools to handle complex decisions under uncertainty, and which may have multiple objectives (2:3). The utilization of these tools can help define and understand the interrelationship of factors in order to explicitly model corps artillery.

2.1.1 Influence Diagrams. An influence diagram is a decision analysis tool used to depict and solve a decision problem. The influence diagram provides a simple graphical representation of a decision. Its design captures the major factors that bear upon a problem without showing so much detail so as to confuse the issue. Clemen describes the construction of influence diagrams for decisions involving uncertainties. He uses ellipses for chance events, rectangles for decision nodes, and octagons for decision outcomes or value nodes. Arrows represent relevance of events to one another (2:34). The influence diagram in Figure 1-3 shows the basic elements that impact the modeling of corps artillery. A decision node represents the potential assignment of a tactical mission. The three possible alternatives for this node for corps artillery would be R, GS-R, or GS. A chance node depicts uncertainties, such as operational posture, since each of these factors will vary. A chance node also represents the five fundamentals of organizing for combat as uncertainties in the diagram. Finally, the outcome achieved from the diagram will be the organization for combat. It is important to note that the time frame for the organization for combat is event driven and not time driven. This is beneficial since the maneuver corps may experience multiple mission changes in a short period of time. Since

the J-STOCHWAR is also event driven, there will be no disconnect with the model. Thus, the influence diagram is a concise display of the factors that are relevant to model corps artillery. Decision makers can quickly identify the relationships among the factors in the problem.

2.1.2 Decision trees. The decision tree is another decision analysis tool that will be useful in modeling corps artillery. Clemen says that decision trees show more surface detail than an influence diagram and are more beneficial to represent the minutia of decision problems. Similar to influence diagrams, circles and squares represent events and decisions, respectively (2:49). The results of a decision tree are to the right of each branch. Figure 2-1 depicts a portion of the influence diagram in a decision tree. Decision trees will be useful to solve uncertainties, such as terrain and weather; however, a decision tree cannot represent the entire problem. Decision trees tend to get very cumbersome and unmanageable for more complex problems (2:55).

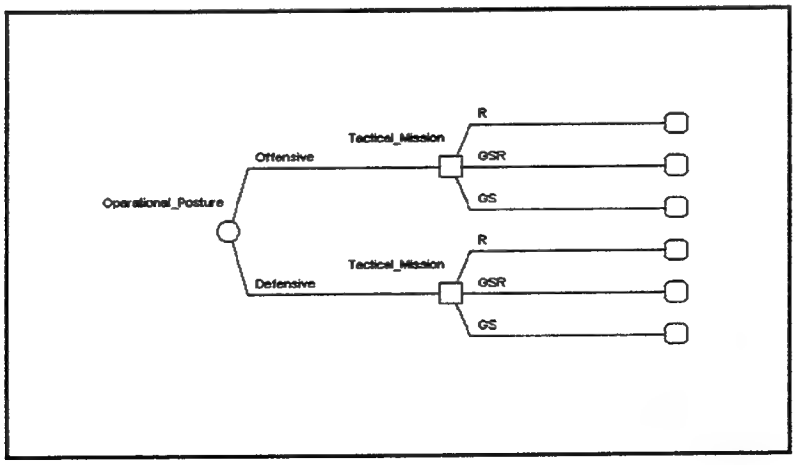


Figure 2-1 Decision Tree Depicting Operational Posture Uncertainty

Thus, both influence diagrams and decision trees are complementary techniques and each provide insight into decision problems. The influence diagram omits a lot of the specific details, but it focuses on the problem in a more aggregate, manageable fashion that still captures the critical aspects of the problem. The decision tree shows more detail and specificity, but it becomes unmanageable as problem complexity increases. For these reasons and due to the size of the problem, the methodology section uses influence diagrams. There are many decision analysis solvers on the market; however, the Decision Programming Language (DPL™) Version 3.1 was selected to handle this problem.

2.2 Combat Models

Several combat models offer examples of artillery algorithms that model corps artillery. All of the models address corps artillery; however, each model deals with corps artillery in a different way. The development of the model for incorporation in the J-STOCHWAR may use important aspects of each combat model. Models examined include the Concepts Evaluation Model (CEM), the Force Evaluation Model (FORCEM), the Tactical Warfare Model (TACWAR), and the Joint Theater Level Simulation (JTLS).

2.2.1 Concepts Evaluation Model (CEM VI)

CEM is a deterministic theater-level model that simulates combat between two opposing forces. The primary inputs for the model are (1) the forces and resources allocated to the theater by the opposing nations, and (2) information on the outcome of brigade-level engagements. The outputs from the model are the Forward Edge of the Battlefield (FEBA) location and the condition of the opposing forces resulting from the consumption and/or depletion of resources (18:1-1 to 1-3). CEM discretely represents

direct support and general support artillery; however, it does not distinguish corps artillery as an operational asset. All non-divisional assets (corps artillery) are simply combined into a single status file with no explicit mission assignment. Allocation of corps artillery supports strength on offense and weakness on defense. For each division on line, a division force ratio (DFR) is calculated: a friendly-to-enemy DFR if the maneuver corps has on offensive mission, or an enemy-to-friendly DFR if the corps has a defensive mission. Next, the corps artillery units available for allocation in the single status file are converted to an equivalent number of artillery battalions. Finally, equivalent battalions are allocated among the divisions on line in proportion to $DFR/\sum DFR$, where the sum is taken over all divisions in the corps on line. For attrition purposes, the Attrition Calibration Model (ATCAL) handles the corps artillery fires exactly like the direct support artillery (18:1-13).

For use in J-STOCHWAR, CEM offers no advantages. CEM implicitly models corps artillery and fails to adequately capture the benefits of these assets. As such, CEM does not model the five fundamental factors associated with assigning a tactical mission to corps artillery units, which is what we seek in the J-STOCHWAR.

2.2.2 Force Evaluation Model (FORCEM). FORCEM represents the actions of Air/Land forces in a theater of operations for an extended period of time (up to 90 days). It is also a deterministic, average value model, which allows no flexibility for player interaction with the model except to provide the initial forces to participate in the simulation (16:F-15). FORCEM is a more transparent model than CEM because it models more of the elements associated with force-on-force combat, and it offers more insight

into the interaction of combat processes. The three basic elements of the model are: simulated terrain and physical environment, units that operate in this environment, and functional processes or operations performed by the units (16:F-15 to F-16). Additionally, unlike CEM, FORCEM does model corps artillery as a separate operational asset.

FORCEM assigns a mission of GS, GS-R or R to corps artillery units. However, these three missions have different meanings than the standard tactical missions. The three missions with their corresponding meanings are as follows (13:7-8):

R Field artillery battalions whose fires exclusively augment those of a division.

GS Field artillery battalions who fire exclusively for the corps headquarters.

GS-R Field artillery battalions who fire first priority for the corps headquarters, and secondly augment divisional fires.

This is much better than CEM; however, FORCEM fails to provide the decision logic for the assignment of each tactical mission. The tactical mission assignment is based on the weapon asset number, or a user defined number which flags a battalion by its weapons characteristics, and the desired tactical mission inputted by the user. Thus, the steps and user logic to determine the type of tactical mission are missing in FORCEM.

For use in the J-STOCHWAR, FORCEM offers some advantages and disadvantages. The first advantage is that FORCEM contains an algorithm to model corps artillery. Once artillery units are assigned a specific tactical mission , they are partitioned into a fire support set. Units assigned a mission of *reinforcing* are filed in a set of assets available for support to divisions (close support fires). These fires contribute to division level combat through the Combat Sample Generator Model (COSAGE) and ATCAL model results. Artillery units assigned a *general support* mission are filed in a set of fire

support battalions available to the corps. These units do not fire in support of forward combat, but are instead the cornerstone units to fight the deep battle (counterfire and interdiction). Similarly, units with a *general support reinforcing* mission fire in the deep battle as first priority and are also filed in the set of units available to reinforce engaged maneuver elements (17:38-39). Attrition that results from the fires of GS and GS-R units are calculated directly in FORCEM using the "Superquickie" model. The "Superquickie" is a target damage model that requires a definition of the target area and input data to support the munitions and caliber of each delivery weapon system (17:A-2). In this manner, FORCEM allocates all corps artillery into specific sets for each tactical mission: GS, GS-R, and R.

A second model advantage is asset positioning. FORCEM positions artillery units throughout the corps sector based on the tactical mission assigned to the unit. Units with a general support mission are positioned along the center azimuth of the most forward division with two-thirds range of the unit's weapon asset in front of the forward line of troops (FLOT). FORCEM positions units with reinforcing and general support reinforcing missions similarly (17:38-39).

Although FORCEM provides more detail about artillery representation, it does have some disadvantages. FORCEM lacks the decision logic for the assignment of a tactical mission. A second disadvantage is FORCEM is deterministic and the J-STOCHWAR is stochastic.

2.2.3 Tactical Warfare Model (TACWAR). TACWAR is yet another theater-level model. Its primary purpose is as a research and evaluation tool. TACWAR includes

force mix capabilities at an aggregated level. TACWAR is basically a deterministic, time-stepped model which allows some user interface (11:132-133). Like most of the other theater-level models, TACWAR does not explicitly model corps artillery assets. Thus, since TACWAR fails to model uncertainty and does not capture the features of corps artillery as an operational asset, it offers no advantages for use in the J-STOCHWAR.

2.2.4 Joint Theater Level Simulation Model (JTLS). JTLS also models theater-level operations. JTLS serves as both an operations support and a force capability tool to assess combat between different force mixes or resources. JTLS is a deterministic model which uses Lanchester-based methods to simulate combat (16:J-21). Deterministic lanchester methods involve the use of differential equations to represent the dynamics of different forms of warfare. These equations are simple representations of combat, and fail to capture all of the idiosyncrasies of modern combat such as tactics, C3I, and suppression (12:63-64). JTLS does not explicitly model corps artillery. As such, JTLS offers no advantages for use in the J-STOCHWAR.

2.2.5 Model Summary. For allocation purposes, FORCEM offers the best concepts for use in the modeling of corps artillery in the J-STOCHWAR. FORCEM is the only theater-level model which attempts to doctrinally model corps artillery by assigning tactical missions; however, it would require significant modification for use in the J-STOCHWAR. The other models do not account for uncertainty in assigning a tactical mission, or fail to model corps artillery at all.

All of the models treat randomness via deterministic methods and use deterministic attrition algorithms. J-STOCHWAR will also use deterministic attrition algorithms;

however, attrition is not in the scope of this thesis. Table 2-1 shows a summary of all the models.

Table 2-1. A Comparison of Corps Artillery Modeling Techniques

	CEM	FORCEM	TACWAR	JTLS
Allocation	All assets placed into single access file. Allocated based on force ratios.	Units flagged with specific tactical mission based on user input.	All assets placed into single access file. Allocated based on player selection.	All assets placed into single access file. Allocated based on player selection.
Tactical Missions	GS	GS, GS-R, R	None	None
Attrition	ATCAL	Superquickie	ATCAL	Lanchester based equations
Sidedness	Two-sided Symmetric	Two-sided Symmetric	Two-sided Reactive Asymmetric	Two-sided Asymmetric
Treatment of Randomness	Deterministic	Deterministic	Deterministic	Deterministic

2.3 Army Doctrine

Theater-level models such as CEM and FORCEM offer some insight into the problem of modeling corps artillery. Another area which requires examination is the area of artillery doctrine. Army artillery doctrine dictates the "real world" norms and fundamentals of artillery employment. The 6-Series field manuals and training circulars contain the majority of field artillery doctrine, and *Field Artillery* (14), a bi-monthly professional bulletin, disseminates current knowledge and information as to the progress

of field artillery in updating and validating doctrine. The solution methods utilized in the J-STOCHWAR should reflect current doctrine as outlined in these sources.

2.3.1 Field Manual 6-20 (Fire Support in Combined Arms Operations). When field artillery is retained under corps control, the corps commander must assign these units a tactical mission. When the commander assigns a specific mission to the corps artillery, then all the battalions within the corps artillery will adopt the same mission. Only the corps commander can subassign missions if necessary. This technique is called tactical tailoring of the artillery. Currently, none of the Army theater-level models have the ability or flexibility to adequately model this fundamental doctrine. An artillery unit can receive one of the four following tactical missions (6:1-11 to 1-13):

(1) Direct support. A unit assigned a mission of DS is immediately responsive to the field artillery support needs of a particular maneuver element, normally a brigade. A DS unit furnishes close, continuous fire support to the supported maneuver element and must coordinate its fires with the plans of the maneuver element. The essential feature of the DS mission is that a DS artillery unit may provide fire support to only one maneuver element. The DS mission is the most decentralized, demanding, and complex of the standard tactical missions.

(2) Reinforcing. A unit assigned a reinforcing mission provides augmenting fires to meet the overall support needs of the supported maneuver force. The reinforcing unit remains under the command of the force artillery commander, but its fires are planned and controlled by the reinforced unit. An artillery unit can reinforce only one other artillery unit. The reinforcing mission is also highly decentralized, being second only

to the DS mission in degree of control.

(3) General-support reinforcing. This mission requires a field artillery unit to furnish fires for the force as a whole as its first priority and reinforcing fires to another FA unit in second priority. A unit with this mission remains under the control of the force artillery commander. The GS-R mission provides flexibility to meet the needs of a variety of tactical situations. Only one of the two parts can be done at a time--either it is acting in its GS capacity or it is performing its reinforcing role. GS-R units will normally receive ammunition restrictions to preclude conflicts in fulfilling both priorities.

(4) General support. A unit with this mission provides responsive field artillery to the needs of the force commander. Artillery assigned to this mission is sometimes referred to as the corps commander's "hip pocket" artillery. A general support mission is the most centralized of the standard tactical missions.

Corps artillery units are not assigned a mission of DS. This mission is specifically assigned to division level artillery units. The method of determining the specific tactical mission follows from a set of guiding principles for organizing for combat.

(1) Adequate field artillery support for committed combat units. Artillery support is the most responsive to committed maneuver forces when it has a mission of DS. The minimum adequate fire support for committed units is one FA battalion in direct support of each maneuver brigade. In order to maintain unity of command, there cannot be more than one FA unit in direct support of each committed brigade. Additional support is achieved by assigning other FA units the mission of reinforcing or general support reinforcing. It is ammunition allocation that ensures the adequacy of this support.

Additionally, general support units can provide support if they are positioned properly (6:1-15).

(2) Weight to the main attack in offense or most vulnerable area in the defense. This principle can be accomplished in any of the following ways:

(a) A tactical mission of R or GS-R can be assigned to provide additional responsive fires to engage maneuver forces.

(b) FA units can be positioned and assigned directions of fire to concentrate their fires in the appropriate sector or zone. Thus, units with the mission of GS can add weight to the main attack or strengthen the most vulnerable area.

(c) Ammunition can be allocated to provide more support in the affected area (6:1-15).

(3) Facilitate future operations. This principle is essential to ensure success in the face of unforeseen events and to ensure smooth transition from one phase of an operation to another. The principle can be implemented through the assignment of tactical missions, positioning, and ammunition allocation. The assignment of an on-order mission permits a unit to anticipate a fire support need in the future. An alternative method to facilitate future operations is to modify the current tactical mission in accordance with anticipated requirements. An example of this method would be to restrict the ammunition expenditure in the current mission to ensure its availability later (6:1-15).

(4) Immediately available field artillery support for the commander to influence the action. The force field artillery commander retains some artillery with which the force commander can influence the action. This is done by assigning GS or GS-R

missions to artillery units, making them responsive to the force commander (6:1-16).

(5) Maximum feasible centralized control. Artillery is most effective when control is centralized at the highest force level consistent with the fire support capabilities and requirements of the overall mission. Centralized control of FA units permits flexibility in its employment and facilitates effective support to each subordinate element of the command and to the force as a whole. Each standard tactical mission represents varying degrees of centralized control and responsiveness to committed units. The optimum degree of centralized control varies with each tactical situation. Fighting today's battles will require more centralization because of the limited resources available to attack targets and the need for carefully coordinated employment of acquisition, attack, and assessment means.

A high degree of centralized control is desired in a defensive situation. Since the enemy has the initiative, it is difficult to accurately predict where and when he will attack. Therefore, to ensure that he can influence the action wherever it may develop, the force commander retains more control of his artillery through greater centralization.

A lesser degree of control is required in an offensive situation because the support force has the initiative. To help the close combat elements retain the initiative and maintain the momentum of the attack, the force commander may grant subordinate FA commanders wider latitude. This allows the artillery to be more responsive to the fire support needs of the maneuver elements of the force (6:1-16).

In summary, FM 6-20 outlines the doctrine of command relationship, tactical missions, and the five guiding principles to adequately model corps artillery as an

operational asset.

2.3.2 Field Manual 6-20-30 (Fire Support for Corps and Division Operations). The maneuver corps conducts offensive, defensive, and other types of operations. For each of these types of operations, the corps artillery will receive a specific tactical mission to facilitate fire support. Additionally, the positioning of corps artillery assets is affected by the specific maneuver corps operation. Since the J-STOCHWAR only models offensive and defensive operations, other types of operations such as passage of lines and operations other than war are not in the scope of this problem.

During offensive operations corps artillery units are positioned forward to take advantage of their range and to influence the deep battle. Units will be positioned so that at least two-thirds of their range extends beyond the maneuver force. For offensive operations, corps artillery will receive a preponderance of reinforcing and general-support reinforcing mission assignments (7:4-4 to 4-6). However, mission assignments and positioning will change for defensive operations.

During defensive operations, corps artillery units are initially positioned forward, but they must be prepared to move rearward based on the flow of battle. For defensive operations, corps artillery units will receive a preponderance of general support missions due to control purposes and range considerations (7:5-8 to 5-9). Thus, the specific mission assignment and initial positioning guidance will vary for each corps artillery unit based on the type of maneuver corps mission.

2.4 Summary of Literature

Both influence diagrams and decision trees offer excellent capabilities to help

determine tactical mission assignments and positioning of corps artillery assets. These tools can be used along with current artillery doctrine and information drawn from other theater-level models to model corps artillery in the J-STOCHWAR. Theater-level models offer very limited benefits since most previous models are deterministic in nature and fail to model the uncertainty which the J-STOCHWAR attempts to capture. Nevertheless, some of these references will be useful in modeling corps artillery in the J-STOCHWAR.

III. SOLUTION TECHNIQUE

3.1 Steps in Organizing for Combat

3.1.1 Command Relationship. In organizing corps artillery units for combat, the first step to consider is to place a unit into an organization using a command relationship. There are four types of command relationships--organic, assigned, attached, and operational control (6:1-11). For the field artillery, the most common and appropriate action is attachment. Attachment allows the receiving commander to alter the organization of the attached unit. This is important at corps level so that field artillery battalions may be attached to an FA brigade as depicted in Figures 1-1 and 1-2. Once the FA brigade is formed, the corps commander may attach one or more FA brigades to a subordinate maneuver unit such as a division, armored cavalry regiment (ACR), or separate brigade (5:4-1).

3.1.2 Tactical Mission. Having established the command relationship, the second step is for the commander to give the units which he controls a tactical mission. Tactical missions are most often given to battalions, but as discussed earlier may be given to an FA brigade as a whole. Tactical mission assignments in the J-STOCHWAR will encompass both FA battalions and FA brigades.

3.1.3 FA Brigade Employment. Once the FA brigade is formed, it can be employed in one of three ways: under corps control, attached to a separate maneuver brigade or ACR, or attached to a division.

When the FA brigade is retained under corps control, the corps commander must provide it with a tactical mission. Once he establishes the mission assignment, then the

battalions within the brigade all adopt the mission given to the FA brigade (5:4-2). The FA brigade commander cannot subassign missions to the attached battalions unless authorized specifically by the corps commander.

If the FA brigade is attached to a separate maneuver brigade or ACR, the maneuver commander assumes command and control of the brigade. The maneuver commander will now assign tactical missions to the FA battalions with the advice of the FA brigade commander.

Finally, if the FA brigade is attached to a division, then the division commander assumes command and control of the brigade. Once he receives the brigade, the division commander will sub-attach it to his division artillery for unity of command. The division artillery commander will advise the division commander on mission assignments, and it is this decision process the methodology attempts to model.

3.2 Rules and Guidelines for Organizing for Combat (5:HO-5)

In following the steps outlined above, there are also some basic rules and guidelines that dictate how artillery is organized. These rules, listed below, are not stringent standards, but provide a framework to make the process easier to understand.

1. Assign one DS battalion for each committed maneuver brigade. This is not required for a brigade in the reserve role, but could still be done if the situation warrants i.e. rear area combat operations (RACO). When a maneuver brigade in reserve is committed, it will have its DS FA battalion in support. This rule is helpful in establishing the direct support for a division or separate brigade; however, this rule will not affect corps artillery organization for combat since the DS mission is not considered.

2. Assign direct support and general support missions only to division artillery units. Assign reinforcing, general support-reinforcing, and general support missions to corps artillery units.

3. Do not have more than two reinforcing battalions to any one direct support battalion (this includes both reinforcing and general support-reinforcing missions). This rule supports the fundamental of weighting the main attack in the offense or strengthening weakness in the defense. More than two battalions could be assigned to reinforce a DS battalion; however, this may cause inadequate fire support for the supporting attack.

4. A reinforcing battalion can only reinforce one FA battalion. Attempting to reinforce more than one other battalion places the reinforcing unit in danger of running out of ammunition and may cause conflicts in responding to requests for fire.

5. Assign on-order (o/o) tactical missions to units to help facilitate future operations. On-order missions alert a unit to consider its support requirements for possible follow-on operations (6:1-5). However, caution must be exercised when assigning on-order missions since it becomes extremely difficult to transition from one mission to another in certain instances. Specifically:

a. DS o/o R is possible but a hard to do mission based on the responsibilities to the supported unit. A better solution is DS o/o GS-R or DS o/o GS.

b. R o/o DS is also a hard mission to do based on the responsibilities the unit has to the unit it is reinforcing. If you do this, consider imposing ammunition constraints while in the R role.

c. DS o/o DS should be avoided due to the problems with fire supportpersonnel requirements. Also, this would cause you to constrain ammunition in the DS mission.

6. Offense -- decentralize (more R than GS-R)

Defense -- centralize (more GS-R than R)

3.3 Assumptions

The solution technique uses the following assumptions in the organization for combat process using the steps and guidelines described above:

1. The corps artillery is attached to the maneuver corps.

2. The corps artillery consists of three FA brigades as shown in Figures 1-1 and 1-2.

3. Each FA brigade contains three FA battalions and is organized as shown in the organization chart in Figure 1-1 or Figure 1-2. The weapon systems are indicative of the type of division the corps artillery is supporting.

4. All of the maneuver divisions retain their direct support artillery.

5. The initial organization for combat will be doctrinally based and does include perceptions of the enemy which may cause tactical tailoring of the artillery later in the simulation.

3.4 Methodology Overview

The solution technique incorporates the above assumptions. The assignment of tactical missions will be done in two phases. In the first phase, a decision rule will be

established to assign a tactical mission to each FA brigade, and in the second phase, each FA battalion will receive its tactical mission. In each phase, the task organization process is shown for both offensive and defensive missions.

3.5 Phase I: FA Brigades

The tactical mission assignment for each FA brigade will follow from the Field Artillery Force Allocation Rules generated from the Army of Excellence (AOE) force design (14:16-19). The allocation rules establish the following FA brigade tactical mission assignments during both offensive and defensive operations:

1. Each maneuver corps will receive a general support brigade consisting of three MLRS battalions behind each maneuver corps. This brigade will remain under corps control for employment purposes.

2. Each heavy division within the corps will receive one reinforcing brigade consisting of two MLRS battalions and one 155mm self-propelled battalion. Each of these brigades will be attached to the division for employment in combat.

3. Each light, airborne, or air assault division within the corps will receive one reinforcing brigade consisting of three 155mm towed battalions and one target acquisition battery. These brigades will also be attached to the division for employment.

As an example of these allocation rules, consider a heavy maneuver corps containing two armored divisions and one mechanized infantry division. The corps artillery would consist of four FA brigades and have the following task organization:

3.6 Phase II: FA Battalions

The tactical mission assignment of each FA battalion will follow the steps and rules

outlined in Sections 3.1 and 3.2. Additionally, the tactical mission assignment for each battalion will vary depending on the type of mission the maneuver corps is conducting.

Table 3-1. Task Organization

Unit	FA Brigades	Tactical Mission	Composition
Corps	1	GS	3 - MLRS Bns
Armored Division	1	R	2 - MLRS Bns 1 - 155mm SP Bn
Armored Division	1	R	2 - MLRS Bns 1 - 155mm SP Bn
Mech Infantry Division	1	R	2 - MLRS Bns 1 - 155mm SP Bn

3.6.1 Offensive Operations. The FA brigade assigned the mission of GS is retained under corps control. The FA battalions that compose this brigade are also assigned a tactical mission of GS since this follows from the guidelines set forth in the employment of FA brigades under corps control.

The tactical mission assignment for the FA battalions that compose the reinforcing brigades is not as straightforward. Each of these battalions can receive any of the three missions: GS, GS-R, or R. The influence diagram in Figure 3-1 depicts the interrelationship of factors associated with this mission assignment process.

By adhering to the rules and guidelines associated with organizing field artillery for combat, each of the five fundamentals were input as factors affecting the decision for tactical mission assignment.

1. Adequate Field Artillery Support. Additional support is achieved in offensive operations by assigning FA brigade units with R or GS-R missions. Although both

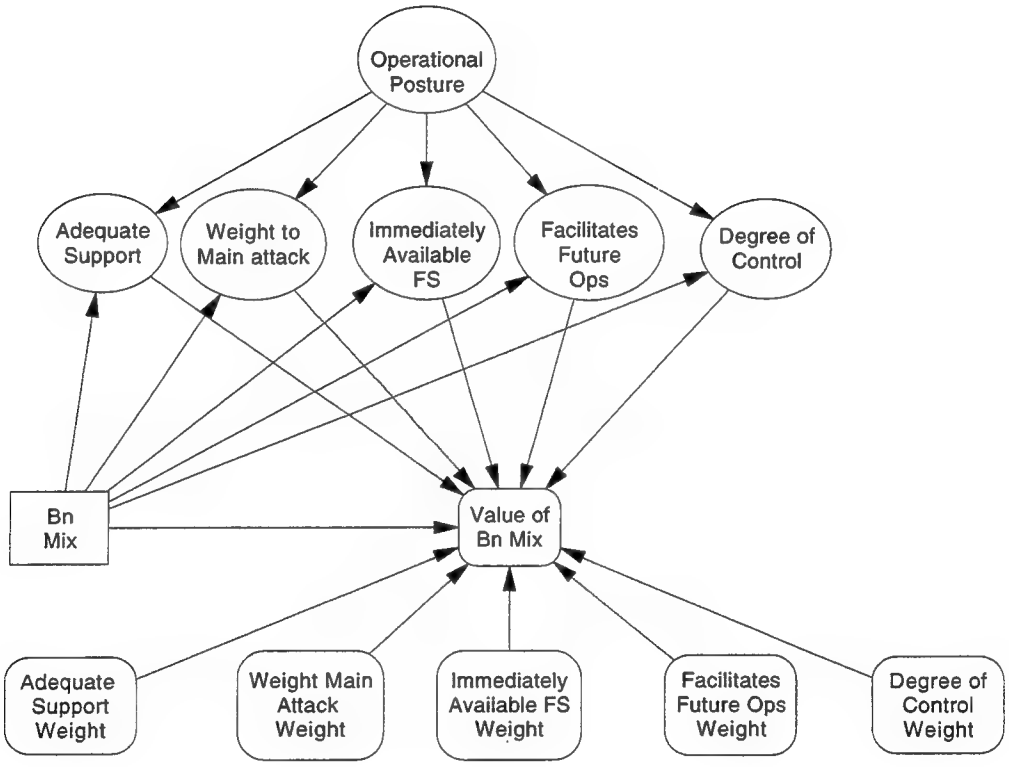


Figure 3-1. Influence Diagram for Determining Tactical Mission Assignment

missions provide adquate support, the reinforcing mission has less restrictions, is more responsive and has more flexibility in the allocation of ammunition and fires. Therefore, the R mission is somewhat better than the GS-R mission and one would expect to see more of this type of mission assignment in offensive operations. The overall level of support and the contribution of this fundamental depends on the mission assignment. The three possible states of nature for this fundamental are *adequate*, *marginal*, and *not adequate*.

2. Weight to the Main Attack. A tactical mission of R or GS-R can be assigned to a unit to provide weight to the main attack. For the same reasons expressed in (1) above, the R mission is a better tactical mission assignment than GS-R. Additional weight is also provided by units with a mission of GS since these units would be the division commander's "hip pocket" artillery. The states of nature for this fundamental are *provides weight*, *provides marginal weight*, and *provides no weight.*

3. Facilitate Future Operations. This principle can be implemented through the assignment of on-order (o/o) missions. The assignment of an on-order mission permits a unit to support the current offensive operations, and consider the requirements such as ammunition allocation and positioning for future support missions. As mentioned in Section 3.2, the rules for assigning on-order missions would suggest that R o/o GS-R or GS-R o/o GS would best facilitate future operations. The inputs into the influence diagram reflect that the assignment of on-order missions is weighted greater than not assigning an on-order mission. The two states of nature for this fundamental are *helps facilitate* and *does not help facilitate*.

4. Immediately Available Field Artillery Support. The commander can best influence his availability of fire support by assigning a unit a GS or GS-R mission. The GS mission is preferred because it does not have as one of its priorities the reinforcing requirements. The inputs for this fundamental weight the GS mission greater than the GS-R mission. Immediate support is achieved by having fires available upon initial request. Fires which could not be delivered within 20 minutes would be considered not immediate. Thus, the three states of nature for this fundamental are *available now*, *available within 10 minutes*, and *available after 20 minutes*.

5. Maximum Feasible Centralized Control. Offensive operations require decentralized control of field artillery units. This is accomplished by assigning more R missions than GS-R. The inputs for "Control" in the influence diagram reflect this by providing additional weight for R missions. The two states of nature for this fundamental are *centralized* and *decentralized.*

Thus, for offensive operations one would anticipate that the FA battalions for each reinforcing brigade should be assigned either a reinforcing or general support mission. Mission assignments of this type will maximize the effect of each fundamental for organizing for combat in the offense.

3.6.2 Defensive Operations. Similar to offensive operations, the FA battalions that compose the FA brigade under corps control will be assigned a GS mission during defensive operations. However, the tactical mission assignments for the FA battalions in the reinforcing brigades will vary. The influence diagram in Figure 3-1 also applies to defensive operations; however, the effect of each factor differs for defensive operations.

The same rules and guidelines associated with organizing field artillery for combat apply to defensive operations as well as offensive operations. The states of nature are also consistent with those in offensive operations. Each of the five fundamentals are factors affecting the decision for tactical mission assignment.

1. Adequate Field Artillery Support. Adequate support in defensive operations is accomplished by assigning FA battalions a tactical mission of R or GS-R. Although both missions provide the additional support, the GS-R mission is preffered in defensive operations. The GS-R mission allows the commander more flexibility in the defense due to the inherent dual purposes of a GS-R battalion. Since units assigned this mission are not specifically designated to support one DS battalion, the commander can better allocate ammunition to cover weak areas in his defense throughout his area of operations. Therefore, the GS-R mission is better than the R mission in defensive operations, and one would anticipate seeing more of this type of mission assignment in defensive operations.

2. Weight to the Main Attack. A tactical mission of R or GS-R will provide the best support for the most vulnerable area of the defense. For similar reasons as expressed in (1) above, the GS-R mission better facilitates support in the main attack area. A GS-R mission allows the commander to restrict ammunition expenditures in the defense so that he has ammunition available to support a possible offensive push if he stops the enemies attack. Additionally, weight is provided by units with a GS mission since these units can support the entire area of operations.

3. Facilitate Future Operations. As discussed in Section 3.2, on-order missions best facilitate future operations. Similar to offensive operations, the units assigned an R

will most likely be o/o GS-R and units assigned GS-R will be o/o GS.

4. Immediately Available Field Artillery Support. Availability is best achieved by assigning a unit a GS or GS-R mission. The GS mission is preferred because it does not have additional reinforcing requirements. The inputs for this fundamental weight the GS mission more heavily than the GS-R mission for this reason.

5. Maximum Feasible Centralized Control. Defensive operations require centralized control of field artillery units. This is accomplished by assigning more GS-R missions than R. The inputs for this factor reflect additional weighting for the GS-R mission.

Thus, from the discussion of each fundamental, FA battalions should have predominantly GS-R or GS mission assignments during defensive operations. Mission assignments of this type best reflect the five fundamentals for organizing for combat.

3.7 Entity Definition

The J-STOCHWAR is a low resolution, highly aggregated combat model. As such the basic unit size in the hierarchical military command structure is a brigade. By aggregating the combatants into large units such as a brigade, the J-STOCHWAR is able to decrease the number of simulation entities in the model to a manageable size. However, one drawback to aggregating to brigade level is that the audit trail is lost in tracking the physical performance data or behavioral assumptions of each subordinate unit of the brigade. The simulation entities in the J-STOCHWAR are then combat and support units of the basic size or larger. Hartman states, "Each such unit will possess its own vector of attribute variables which describe its own unique status, capabilities, activity, and

perception of the battlefield" (10:14).

For corps artillery the basic entity size will also be an FA brigade. To explicitly model each FA brigade, an attribute list or a vector of attribute variables must be developed for each brigade to define the specific characteristics of the brigade. The following list of attributes is not exhaustive, but it provides a starting point for identifying the key attributes for each FA brigade:

1. Unit type - Size of combat unit subordinate to the brigade.

2. Location - Information about the location, orientation or azimuth of fire, movement path, movement speed, and final objective of each FA battalion.

3. Mission - The tactical mission assignment for each FA battalion as determined via the methodology in Section 3.6.

4. Command organization - Identification of superior and subordinate units for information and order routing.

5. Logistics state - Available ammunition, fuel, and other supply classes.

6. State of knowledge - Description of unit's perception of friendly and enemy forces, terrain, and obstacles.

Table 3-2 provides an example of how an FA brigade may be represented in the J-STOCHWAR using the attributes above. Using this format, the entities and attributes of each FA brigade can be input into the computer code of the J-STOCHWAR. The number of corps artillery units and FA brigades will be dependent on the initial data base for task organization as developed by the user or analyst.

Table 3-2. Attributes of an FA Brigade with 3 Battalions

Entity:	Description	Example
1	#1 - FA BDE	75th FA BDE
Attributes:		
0	#1 - FA BN type	155mm SP
1	#1 - FA BN location	Lat/Long, AOF: 6300
2	#1 - tactical mission	Reinforcing
3	#1 - command organization	III Corps Artillery
4	#1 - logistics state	5000 rounds, 10,000gals fuel
5	#1 - state of knowledge	offensive operation
6	#2 - FA BN type	MLRS
:	: : :	: : :
11	#2 - state of knowledge	offensive operation
12	#3 - FA BN type	MLRS
:	: : :	: : :
17	#3 - state of knowledge	offensive operation

IV. RESULTS

4.1 Determining Tactical Mission Assignment

4.1.1 Example Description. This section shows how the methodology to organize for combat and the influence diagram in Figure 3-1 can be used to determine the initial tactical mission assignments for an FA brigade. The FA brigade is one of three brigades in a heavy corps artillery. The example includes one FA brigade composed of three FA battalions: a 155mm SP battalion, and two MLRS battalions. The FA brigade's tactical mission is reinforcing to a tank division.

4.1.2 Enumeration of Mission Assignments. Each FA battalion can be assigned one of the three tactical missions: R, GS-R, or GS. Table 4-1 enumerates the 27 possible mission assignments for the three battalions.

Table 4-1. Enumeration of Mission Assignments

Asmnt #	155 SP	MLRS	MLRS	Asmnt #	155 SP	MLRS	MLRS
1	R	R	R	15	GSR	R	GS
2	GSR	GSR	GSR	16	GSR	GS	R
3	GS	GS	GS	17	GS	R	GSR
4	R	R	GSR	18	GS	GSR	R
5	R	GSR	R	19	R	GS	GS
6	GSR	R	R	20	GS	R	GS
7	R	R	GS	21	GS	GS	R
8	R	GS	R	22	GSR	GSR	GS
9	GS	R	R	23	GSR	GS	GSR
10	R	GSR	GSR	24	GS	GSR	GSR
11	GSR	R	GSR	25	GSR	GS	GS
12	GSR	GSR	R	26	GS	GSR	GS
13	R	GSR	GS	27	GS	GS	GSR
14	R	GS	GSR				

To evaluate the utility of all 27 assignments would be cumbersome at best. Additionally, some of the assignments are duplicates since there are two battalions of the same type weapon system. By using a ratio of tactical mission types within a possible assignment and discarding duplicate assignments, the 27 possibilities can be reapportioned into 10 ratio mixes. For example, mission assignment #4 in Table 4-1 contains two R and one GSR mission assignments. As a ratio this equates to 2/3 R and 1/3 GS-R. This ratio technique provides the 10 brigade mission mixes shown in

Table 4-2. The decision node "Bn Mix" in the influence diagram contains these 10 mixes for consideration in arriving at a solution.

Table 4-2. Brigade Mission Mix by Ratio of Mission Type

Mix	R	GSR	GS
A	1	0	0
B	0	1	0
C	0	0	1
D	2/3	1/3	0
E	2/3	0	1/3
F	1/3	2/3	0
G	1/3	1/3	1/3
H	1/3	0	2/3
J	0	2/3	1/3
K	0	1/3	2/3

4.1.3 Operational Posture. The next step in the example is to establish probabilities for "Operational Posture". The operational posture will vary depending on the perceptions about the enemy as determined in the C3I module of the J-STOCHWAR. For this example the "Offense" state of nature was assigned a probability (p_O) of 1.0, and the "Defense" state of nature was assigned a probability (p_D) of 0. This implies that the

tank division will certainly conduct an offensive operation.

4.1.4 Determining Weight Values. Another step in the process of determining a tactical mission for a particular battalion mix is to provide a weight for each fundamental. (Notationally, W_i is the weight for the i^{th} fundamental, where i =1, 2, ...,5) The weight for each fundamental may also vary according to the desires of the commander. If the commander is more concerned about weighting his main attack than facilitating future operations, he may weight that fundamental more heavily. For the example, each fundamental is equally weighted with a value of 0.2. Regardless of the weight values assigned to each fundamental, the additive value of all five fundamental weights should equal one. This will help facilitate comparisions among each of the fundamentals.

4.1.5 Probabilities and Utilities for the 5 Fundamentals. To complete the example set-up, probabilities and utilities must be assigned for each of the five fundamentals for both offensive and defensive operations. Since no previous work has been documented in this area, the probabilities and utilities for each fundamental were determined based on the author's education, training, and 10 years of experience as an artillery officer. Each probability represents the *degree of belief* that the state of nature will occur (2:209). The results of this example were compared to a similar test case with an approved solution provided by the Fire Support and Combined Arms Operations Department of the U.S. Army Field Artillery School to determine its validity.

A subjective probability was determined for the states of nature for each fundamental for both offensive and defensive operations. (Notationally, p_{ij} is the probability of the j^{th} state of nature of the i^{th} fundamental, where i = fundamental number

1-5, and j = state of nature for each fundamental). These probabilities were then input into the influence diagram to help determine the best mix of tactical missions. The probabilities are shown in Table 4-4.

In addition to the probabilities, a utility for each state of nature was also determined. The utilities are also subjective. For the fundamentals "Adequate Support", "Weight to Main Attack", and "Immediately Available", the "best" possible outcome for each state of nature received a utility of 1.0. The marginal or second best possible outcome received a utility of 0.5. Finally, the worst possible outcome has a utility of 0.

For the fundamental "Facilitates Future Operations", the state of nature which supports future operations is 0.8 and the state of nature which does not support future operations has a utility of 0.2.

The utility values for the fundamental "Degree of Control" varies according to operational posture. The utility of centralized control in the defense is 0.8; whereas, the utility of decentralized control in the defense is 0.2. However, if the posture is offensive, the utilities will be opposite. A summary of all the utilities is shown in Table 4-3.

Table 4-3. Utilities for the 5 Fundamentals

State of Nature	Utility
Provides adequate support Provides marginal support Does not provide support	1 .5 0
Provides weight to main attack Provides marginal weight Does not provide weight	1 .5 0
Available now Available within 10 minutes Available after 20 minutes	1 .5 0
Facilitates future operations Does not facilitate future operations	.8 .2
Centralized control Decentralized control	.8/.2 .2/.8

Table 4-4. Influence Diagram Probabilities for the 5 Fundamentals

OFFENSIVE OPERATION													
	ADEQUATE SUPPORT			WEIGHT TO MAIN ATTACK			IMMEDIATELY AVAILABLE			FAC. OPS	FUTURE	DEGREE CONT.	OF
MIX	ADEQ	MARG	NOT ADQ	PRV WT	MARG	NOT WT	NOW	<10 MIN	>20 MIN	SPTS	NOT SPT	CENT	DECENT
MIX A	0.3	0.3	0.4	0.3	0.3	0.4	0.95	0.05	0	0.1	0.9	0	1
MIX B	0.1	0.4	0.5	0.1	0.4	0.5	0.4	0.3	0.3	0.5	0.5	0.7	0.3
MIX C	0.2	0.4	0.4	0.2	0.2	0.6	0.2	0.3	0.5	0.9	0.1	1	0
MIX D	0.7	0.2	0.1	0.7	0.2	0.1	0.7	0.2	0.1	0.1	0.9	0.2	0.8
MIX E	0.9	0.1	0	0.8	0.1	0.1	0.8	0.2	0	0.2	0.8	0.3	0.7
MIX F	0.7	0.2	0.1	0.6	0.3	0.1	0.6	0.2	0.1	0.3	0.7	0.4	0.6
MIX G	0.8	0.2	0	0.8	0.1	0.1	0.6	0.2	0.2	0.4	0.6	0.5	0.5
MIX H	0.7	0.2	0.1	0.7	0.1	0.2	0.5	0.3	0.2	0.7	0.3	0.6	0.4
MIX J	0.5	0.3	0.2	0.5	0.3	0.2	0.3	0.4	0.3	0.6	0.4	0.8	0.2
MIX K	0.5	0.4	0.1	0.5	0.4	0.1	0.2	0.4	0.4	0.8	0.2	0.9	0.1

DEFENSIVE OPERATION													
	ADEQUATE SUPPORT			WEIGHT TO MAIN ATTACK			IMMEDIATELY AVAILABLE			FAC. OPS	FUTURE	DEGREE CONT.	OF
MIX	ADEQ	MARG	NOT ADQ	PRV WT	MARG	NOT WT	NOW	<10 MIN	>20 MIN	SPTS	NOT SPT	CENT	DECENT
MIX A	0.1	0.4	0.5	0.1	0.4	0.5	0.95	0.05	0	0.1	0.9	1	0
MIX B	0.7	0.25	0.05	0.7	0.25	0.05	0.4	0.3	0.3	0.5	0.5	0.3	0.7
MIX C	0.7	0.1	0.2	0.7	0.2	0.1	0.2	0.3	0.5	0.9	0.1	0	1
MIX D	0.3	0.3	0.4	0.3	0.3	0.4	0.8	0.2	0	0.1	0.9	0.8	0.2
MIX E	0.2	0.4	0.4	0.2	0.4	0.4	0.7	0.2	0.1	0.2	0.8	0.7	0.3
MIX F	0.6	0.3	0.1	0.6	0.3	0.1	0.6	0.2	0.1	0.3	0.7	0.6	0.4
MIX G	0.5	0.3	0.2	0.5	0.3	0.2	0.6	0.2	0.2	0.4	0.6	0.5	0.5
MIX H	0.5	0.4	0.1	0.5	0.4	0.1	0.5	0.3	0.2	0.7	0.3	0.4	0.6
MIX J	0.8	0.1	0.1	0.8	0.2	0	0.3	0.4	0.3	0.6	0.4	0.2	0.8
MIX K	0.8	0.1	0.1	0.8	0.2	0	0.2	0.4	0.4	0.8	0.2	0.1	0.9

4.1.6 Value Determination. The final step in arriving at a solution is to determine which mix has the greatest utility once all the probabilities and individual utilities have been input. To do this, the "Value" node in Figure 3-1 contains the equation for computing the overall utility for each mix. The utility for each mix is computed as follows:

$$\textbf{Overall Utility} = [(p_O)*(\Sigma(p_{ij})*(W_i))] + [(p_D)*(\Sigma(p_{ij})*(W_i))]$$

For the example problem the mix with the greatest utility is Mix E with an overall utility of (.804). The results are shown in Figure 4-1.

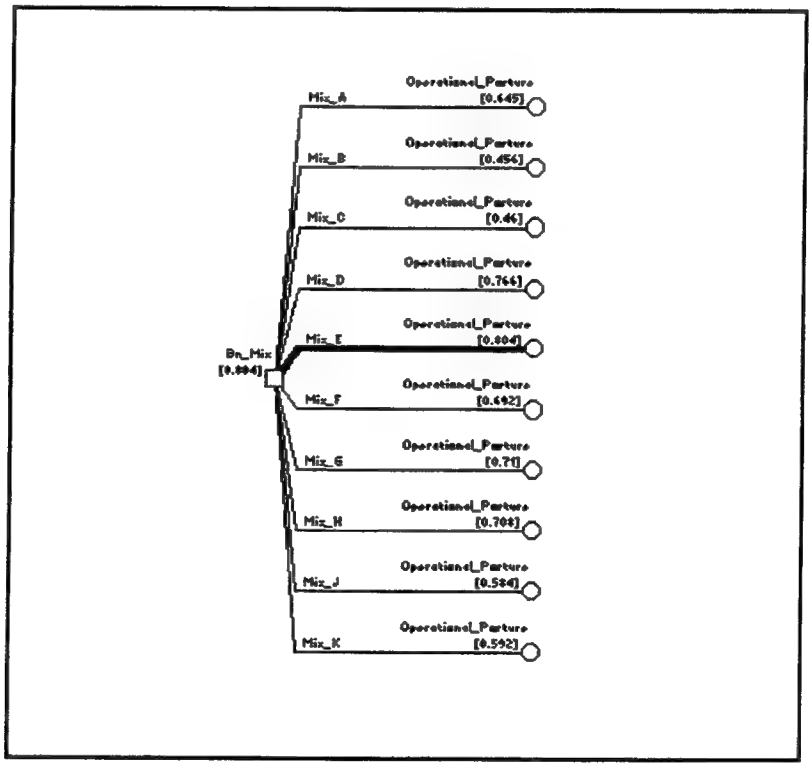


Figure 4-1 Solution to Example Problem

Mix E indicates that the correct ratio in an offensive mission is 2/3 R and 1/3 GS. The question now becomes what mission does each battalion receive? A simple set of

decision rules addresses this question.

4.1.7 Decision Rules. Decision rules will translate the ratio mix solution from the influence diagram into a specific tactical mission for each battalion. The rules are as follows:

1. Due to weapon type range considerations, 155mm howitzers will normally be positioned farther forward than MLRS units. As a result, 155mm units will be located closer to maneuver units. Thus, due to positioning and the inherent responsibilities of a reinforcing unit, it is better for 155mm units to receive an R mission. **If the FA brigade contains both 155mm howitzer and MLRS battalions and the ratio mix solution calls for at least 1/3 R type missions, then the 155mm units should receive the R mission.**

2. For the same considerations mentioned in (1) above it is also better for 155mm units to receive a GSR mission before an MLRS unit. **If the FA brigade contains both 155mm howitzer and MLRS battalions and the ratio mix solution calls for at least 1/3 GSR type missions, then the 155mm units not already given an R mission should receive the GSR mission.**

3. A logical follow-on rule would be to **assign GS missions to MLRS units as much as possible if the ratio mix calls for GS missions and the FA brigade contains MLRS units.**

Using these decision rules, the final solution to the example problem would be to assign the 155mm howitzer battalion an R mission, assign one of the MLRS battalions the other R mission, and assign the second MLRS battalion the GS mission.

4.2 Changes in Operational Posture

As the perception changes in the J-STOCHWAR as to what type of operational mission friendly units will conduct, so too must the organization for combat for artillery units. As the perception changes across the spectrum of being purely offensive or defensive, one would anticipate changes in the ratio mix and the overall utility of the solution.

Table 4-5 shows the resulting utilities as the probabilities change from strictly offense to strictly defense. The optimal mix is highlighted for each operational posture perception.

Table 4-5. Ratio Mix Utilities

Off.	Def.	Mx. A	Mx. B	Mx. C	Mx. D	Mx. E	Mx. F	Mx. G	Mx. H	Mx. J	Mx. K
1	0	.645	.456	.460	.766	**.804**	.692	.710	.708	.584	.592
.9	.1	.639	.477	.476	.750	**.780**	.692	.703	.704	.596	.600
.8	.2	.633	.498	.492	.734	**.756**	.692	.696	.700	.608	.608
.7	.3	.627	.519	.508	.718	**.732**	.692	.689	.696	.62	.616
.6	.4	.621	.540	.524	.702	**.708**	.692	.682	.692	.632	.624
.5	.5	.615	.561	.540	.686	.684	**.692**	.675	.688	.644	.632
.4	.6	.609	.582	.556	.670	.660	**.692**	.668	.684	.656	.640
.3	.7	.603	.603	.572	.654	.636	**.692**	.661	.680	.668	.648
.2	.8	.597	.624	.588	.638	.612	**.692**	.654	.676	.680	.656
.1	.9	.591	.645	.604	.622	.588	**.692**	.647	.672	**.692**	.664
0	1	.585	.666	.620	.606	.564	.692	.640	.668	**.704**	.672

4.3 Survey Results

To help verify the methodology and validate the results obtained in Section 4.2, 12 Small Group Leaders (SGLs) at the Field Artillery School at Fort Sill, Oklahoma provided their "expert" knowledge and input. The SGLs are responsible for teaching organization for combat at the Field Artillery School. The SGLs included 11 majors and one captain. Each had between 10 and 18 years of experience in the field artillery. Nine of the SGLs

are in the U.S. Army, one is in the U.S. Marine Corps, one is from Canada, and one is from the United Kingdom.

Each SGL independently completed an organization for combat survey that exactly replicated the example described in Section 4.1.1 and was used to generate the results in Section 4.1.6. The SGLs provided their appropriate "Bn Mix" at each operational posture perception. The results of the survey are shown in Table 4-6. (Note: One SGL felt the survey was not applicable because trying to emphasize an operational posture perception was unnecessary. Therefore, his results were not included in the final results.)

Table 4-6. Small Group Leader Survey Results

Off.	Def.	SGL 1	SGL 2	SGL 3	SGL 4	SGL 5	SGL 6	SGL 7	SGL 8	SGL 9	SGL 10	SGL 11
1	0	G	F	G	G	G	G	G	G	G	G	F
.9	.1	G	F	H	G	G	G	G	G	G	G	F
.8	.2	G	F	H	G	G	G	G	G	G	G	F
.7	.3	G	F	H	H	G	G	G	G	G	G	F
.6	.4	G	F	H	H	G	G	H	G	G	G	K
.5	.5	G	G	H	H	G	H	H	G	H	G	K
.4	.6	G	G	K	H	K	K	H	J	K	J	K
.3	.7	J	G	K	K	K	K	K	J	K	K	K
.2	.8	J	G	K	K	K	K	K	J	K	K	K
.1	.9	J	G	K	K	K	K	K	K	K	K	K
0	1	J	F	K	K	K	K	K	K	K	K	K

The mode for each operational posture perception was determined from the results in Table 4-6. The SGLs recommended "Mix G" as the appropriate organization for combat when the offensive perception (p_o) ranged from 1 to 0.6. At the 0.5 offense/0.5 defense perception there was a tie between "Mix G" and "Mix H". The mode was "Mix K" when the offensive perception ranged from 0.4 to 0.

4.4 Comparison of Results

A comparison of the survey results and the results obtained using decision analysis with subjective probabilities is shown in Table 4-7.

Table 4-7. A Comparison of Results

		Subject.	Prob.	Results		Small	Group	Leader	Results
Off	Def	Mix	155 SP	MLRS	MLRS	Mix	155 SP	MLRS	MLRS
1	0	E	R	R	GS	G	R	GSR	GS
.9	.1	E	R	R	GS	G	R	GSR	GS
.8	.2	E	R	R	GS	G	R	GSR	GS
.7	.3	E	R	R	GS	G	R	GSR	GS
.6	.4	E	R	R	GS	G	R	GSR	GS
.5	.5	F	R	GSR	GSR	G H	R R	GSR GS	GS GS
.4	.6	F	R	GSR	GSR	K	GSR	GS	GS
.3	.7	F	R	GSR	GSR	K	GSR	GS	GS
.2	.8	F	R	GSR	GSR	K	GSR	GS	GS
.1	.9	F J	R GSR	GSR GSR	GSR GS	K	GSR	GS	GS
0	1	J	GSR	GSR	GS	K	GSR	GS	GS

By comparison, "Mix G" ranked either second or third in the decision analysis results for an offensive operational posture between 1 and 0.5. The significant variation between the two sets of results was the tactical mission assignment for one of the MLRS battalions. It appears that the SGLs were hesitant to assign an MLRS battalion an R mission under an offensive perception. This variation can best be explained by the differences in firepower between a 155mm SP battalion and an MLRS battalion. A modification to the decision rules in Section 4.1.7 could eliminate this difference. **Unless the FA brigade contains all MLRS units, do not assign an MLRS unit an R mission under an offensive operational perception.**

"Mix K" increased in rank from fifth to second as the offensive posture changed

from 0.4 to 0, respectively. The results indicate that **as the perception changes from offense to defense, the tactical mission assignments should not include an R mission.** The decision analysis results reflect this change, but not as quickly as the SGL results. The variation can possibly be explained in the subjective assignment of probabilities; or perhaps in the weights assigned to each fundamental by the SGLs. Overall, the SGL results support the methodology and the results obtained using decision analysis.

4.5 Sensitivity Analysis

The first area of sensitivity analysis was conducted on the weight value nodes using value sensitivity comparison. This type of analysis calculates changes in the expected value or output as one particular value (weight) is varied in the model. The analysis indicates that as the operational posture perception moves away from each extreme--strictly offensive or strictly defensive, the output value or "Bn Mix" changes more frequently. The weight values are most sensitive at the 0.5/0.5 posture level which shows that the uncertainty in operational posture significantly impacts the optimal mix.

The second area of sensitivity analysis analyzed the chance nodes at each operational posture level using probabilistic sensitivity analysis. This type of analysis indicates the variance in the outcome distribution under the optimal mix. The analysis provided two significant results. The least sensitive fundamental over the span of all operational postures is "Facilitates Future Operations" and the most sensitive is "Operational Posture." Thus, overall the sensitivity analysis results reflect the importance of the operational posture level on the final mix.

V. RECOMMENDATIONS

The following sections provide recommendations for implementing the solution techniques and methodology into the J-STOCHWAR and as a decision support tool for the Field Artillery School. Suggestions are made for linking the C3I module with the FA brigade simulation entities, adding battalions to an FA brigade, and some possible follow-on work.

5.1 Linking the C3I Module

The information provided by the C3I module in the J-STOCHWAR is useful in modeling corps artillery in several ways. First, the overall utility gained from the field artillery organization for combat is truly dependent on the operational posture perception provided by the C3I module of the J-STOCHWAR. This perception can be input directly into the chance node "Operational Posture" in the influence diagram in Figure 3-1. Thus, the utility increases as the uncertainty of the type of operation decreases.

Second, the detection and perception update algorithms currently in the J-STOCHWAR are based on the existence of an intelligence collection planning cycle referred to as the perception update cycle. Once a detection has occurred by either side, there are two events triggered in parallel. First, the defending force's deep strike attrition of the attacking (detected) force will be initiated depending on the accuracy of classification and location. Second, depending on the quality of the detection, availability of recon assets and tasking considerations, the detection triggers the event of sending a sensor to the appropriate transit node for detailed reconnaissance. The purpose of the sensor operations is to enable the searching force to build a perception of the enemy's type

and size and then to estimate the enemy's chosen course of action based on the sensor information.

This detection can also be used to trigger events associated with corps artillery. As part of the deep strike attrition algorithm, the corps artillery units assigned a mission of GS can also be fired. In order for these units to be fired, an algorithm must check to see if the distance between the node (physical or transit) of the detected unit and the node which contains the corps GS artillery is less than the range of the asset to be fired. Recall, the position of each FA battalion is input as an attribute of the FA brigade that exercises command and control over that unit. The decision to fire will be based on the detecting unit's course of action as a result of the detection. If the detecting unit's decision is not to conduct a head-to-head engagement based on perceptions of the enemy's size and force ratios, then a corresponding decision must be made as to whether to fire artillery. If the decision is to fire, then there is the risk of being detected by opposing sensors. If the decision is not to fire, then the detecting unit foregoes the opportunity to possibly attrit the opposing force and reduce his force ratio.

A second event that can be triggered by the detection of an enemy force is the orienting and queueing of the detecting unit's counter-battery and counter-mortar radars as part of the sensor operations. The perception update cycle will include the orienting of detecting unit radars in the direction of the node where the detection occurred, and the decision to queue or not.

In order for radars to track incoming artillery, they must be within the range of the radar's capabilities. An algorithm must check to see if the distance between the node

(physical or transit) of the detected unit and the node which contains the radar is less than the range of the radar's maximum range. Second, the radar must be oriented in the proper direction since they are restricted to a 1600 mil search fan. An algorithm must be invoked to orient radar assets in the direction of the detected unit's node. In the counterfire battle, radars will play the paramount role in the detection of opposing force artillery and indirect fire assets.

However, once the radar is properly oriented a decision must be made based on the detecting unit's course of action as to whether the radar should be queued. If the radar is queued, then the detecting unit can track incoming indirect fire systems if they are in range; however, queueing the radar will produce a signal which the opposing force may detect. If the radar is not queued, then the detecting unit's counterfire battle is degraded due to its inability to track incoming indirect fires.

5.2 Adding FA Battalions

The probabilities provided for the example scenario are applicable for an FA brigade with 3 FA battalions. If additional battalions are added to the FA brigade, a different set of decision rules will have to be generated to account for the differences in firepower between the types of units. However, the methodology and ratio technique developed in earlier chapters are applicable for additional battalions. The number of attributes for each simulation entity (FA brigade) will also increase based on the number of additional battalions.

5.3 Follow-on Work

Corps artillery is only one asset available to the corps commander for attacking

targets and synchronizing the deep, close, and rear battles. Other fire support assets available for the commander to consider include chemical and nuclear munitions, air and artillery delivered scatterable mines, air support, naval gunfire, and electronic warfare equipment. Each of these assets provide a unique ability to destroy, neutralize or suppress targets of opportunity and time critical targets.

Although the commander has access to each of these assets, the challenge becomes to select the best asset to attack a particular target based on responsiveness and criticality. Such a problem would involve an assignment optimization that selects the best asset to use. If for example, the assignment optimization routine were to select corps artillery, then the methodology and techniques generated in this thesis would be invoked. If another asset was selected, then a routine to handle that particular asset would be selected.

5.4 Decision Support Tool

The methodology and techniques described in this thesis can also be used by the Field Artillery School to support instruction on organization for combat. Currently, all instruction on organization for combat is based on "prior experience" and not on any quantifiable methods. The results of this work form the foundation for comparing different student task organizations based on resultant utilities. For example, students can compare the utility of their task organization versus the utility of "the approved solution" as determined by the SGLs.

5.5 Conclusions

The proposed methodology and solution technique will provide realistic, doctrinally based tactical mission assignments to explicitly model corps artillery in the

J-STOCHWAR. The subjective probabilities and utilities provide a foundation for future refinements and research. Phase I (Section 3.5) provides the tactical mission assignment for each FA brigade to be input into the J-STOCHWAR. Appendix A depicts a recommended corps artillery force package to support the 64-node scenario in the J-STOCHWAR. Phase II (Section 3.6) provides a quantifiable method to handle the utility of the five fundamentals and an uncertain operational posture in organizing field artillery battalions for combat. The results of both phases provide an organization for combat which reflects real world results.

Finally, the stochastic nature of the influence diagram model also meshes with the architecture of J-STOCHWAR. The operational posture perception node can accept the posture perception provided by J-STOCHWAR. The influence diagram is also flexible enough for inclusion in other theater-level combat models.

APPENDIX A. U.S. ARTILLERY FOR 64-NODE SCENARIO

A. INITIAL FORCES

Army:

Division Artillery

2 Heavy Division Artilleries
1 Light Division Artillery
1 Air Assault Division Artillery
3 Armored Cavalry 155 (SP) Batteries

Corps Artillery

1 Heavy Corps Artillery : 7 MLRS Battalions
2 155 (SP) Battalions

1 Light Corps Artillery: 3 MLRS Battalions
6 155 (T) Battalions
1 Target Acquisition Battery

USMC:

B. REINFORCING FORCES

Army:

Division Artillery

2 Heavy Division Artilleries

Corps Artillery

1 Heavy Corps Artillery: 7 MLRS Battalions
2 155 (SP) Battalions

APPENDIX B. EXPLANATION OF ARTILLERY WEAPONS TYPES USED IN J-STOCHWAR

A. FA1: Missile Launchers (ML)

The missile launchers include the Multiple Launch Rocket System (MLRS) and the Army Tactical Missile System (ATACMS). Both are used primarily in the GS role; however, they may be assigned other tactical missions such as GS-R and R. The missile systems provide extreme firepower at extended ranges. The MLRS has a range of 30 kilometers and can fire a 12 rocket volley before reloading. Each rocket contains 644 dual-purpose improved conventional (DPICM) submunitions. The ATACMS has an unclassified range of 70 kilometers and also fires DPICM.

B. FA2: 155 mm Self-propelled Howitzer (SPH)

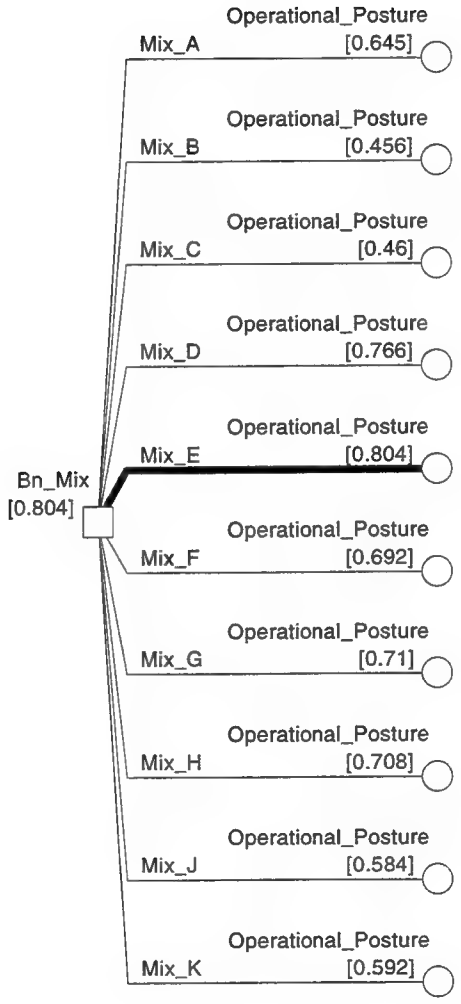
The self-propelled howitzers consist of the M109 series howitzers. These howitzers are used for all tactical missions: DS, R, GS, and GS-R. The newest self-propelled howitzer is the M109A6 "Paladin". The M109 howitzer has a range of 18.1 kilometers without rocket-assisted projectiles (RAP) and a range of 23.5 kilometers with RAP. It fires a variety of projectiles: high explosive, Copperhead, white phosphorous, illumination, DPICM, smoke, nuclear, chemical, and mines.

C. FA3: 155 mm Towed Howitzer (TH)

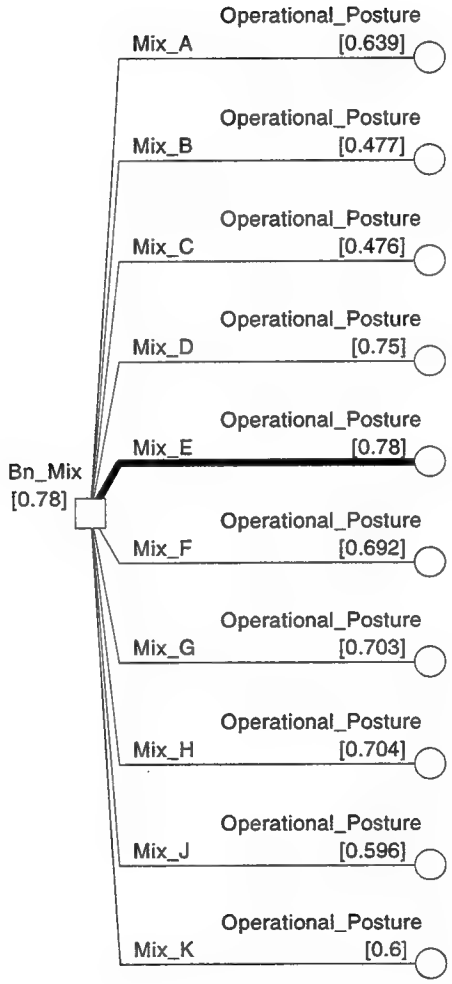
The 155mm towed howitzer is the M198. These howitzers are also used for all tactical missions. This howitzer has comparable ranges to the M109 series howitzers and fires the same projectile types. It is towed by the M925 series 5-ton truck.

APPENDIX C. INFLUENCE DIAGRAM SOLUTIONS

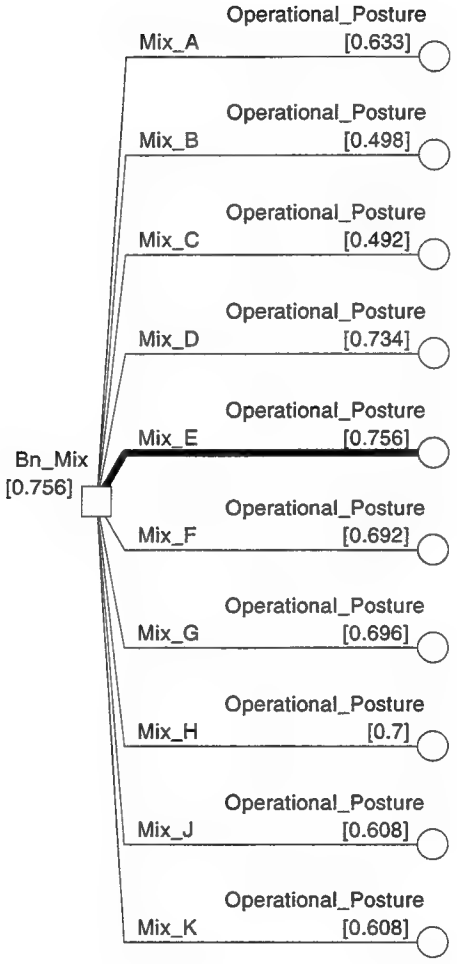
Operational Posture: Offensive 1 / Defensive 0



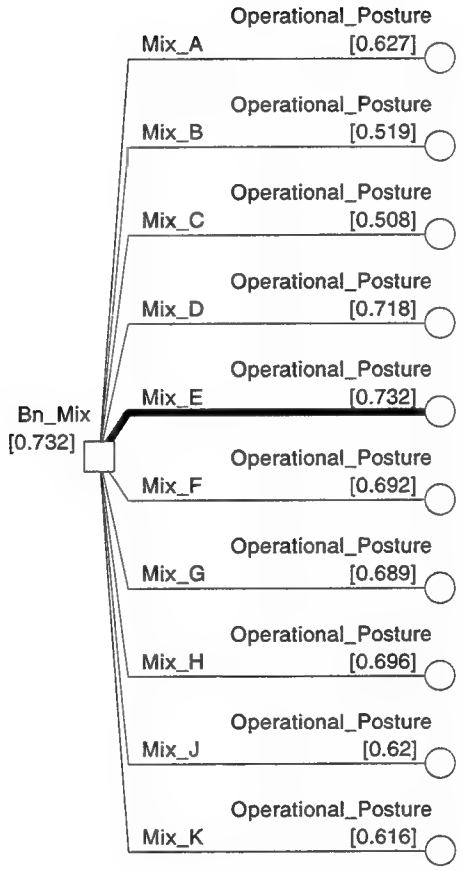
Operational Posture: Offensive 0.9 / Defensive 0.1



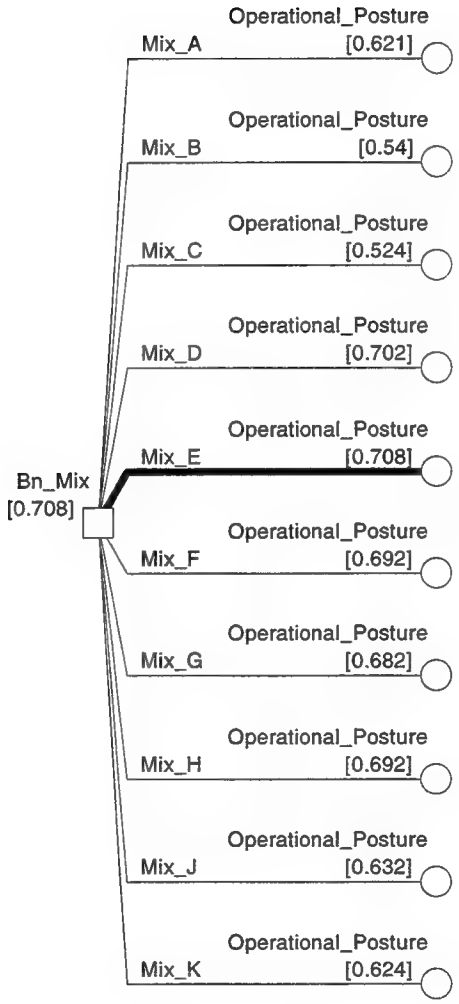
Operational Posture: Offensive 0.8 / Defensive 0.2



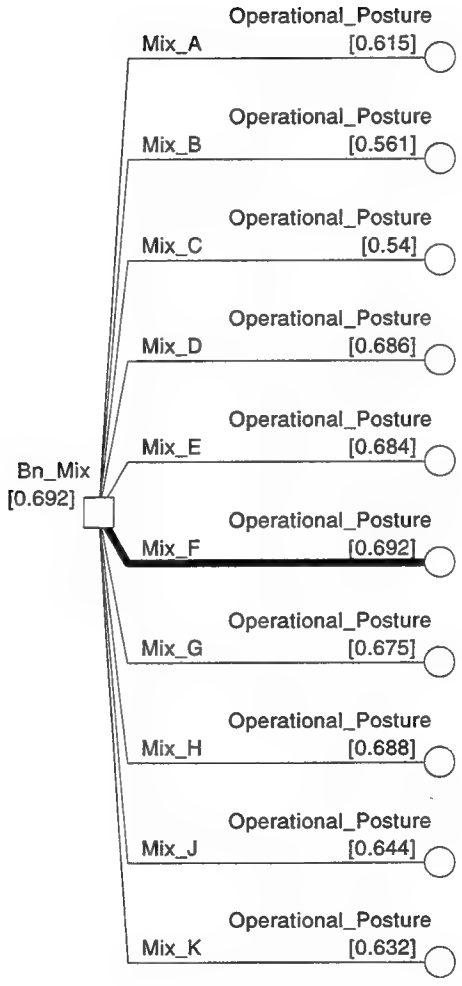
Operational Posture: Offensive 0.7 / Defensive 0.3



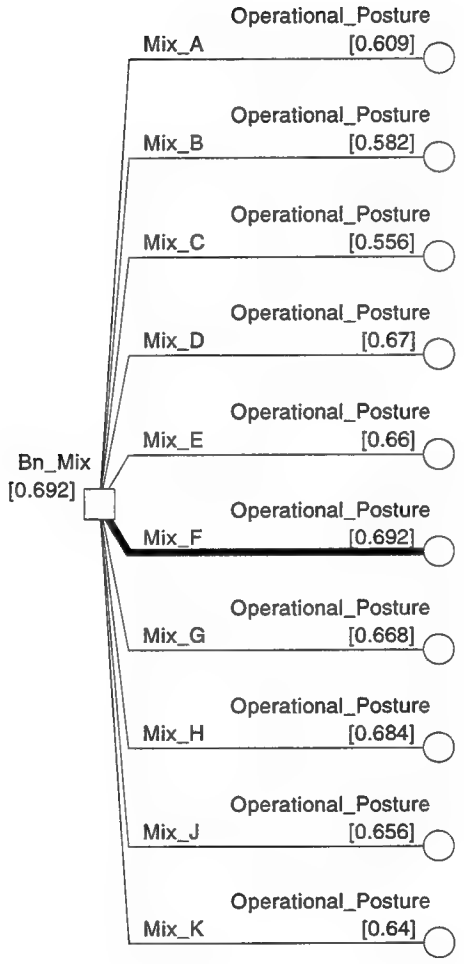
Operational Posture: Offensive 0.6 / Defensive 0.4



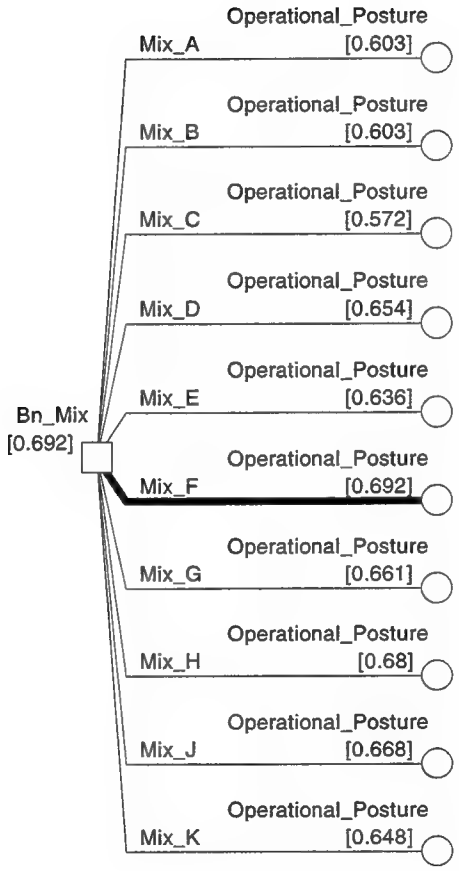
Operational Posture: Offensive 0.5 / Defensive 0.5



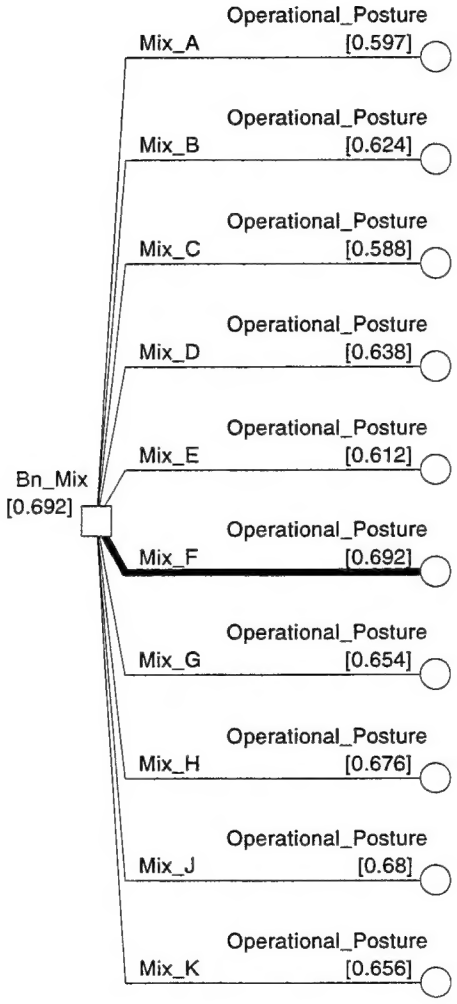
Operational Posture: Offensive 0.4 / Defensive 0.6



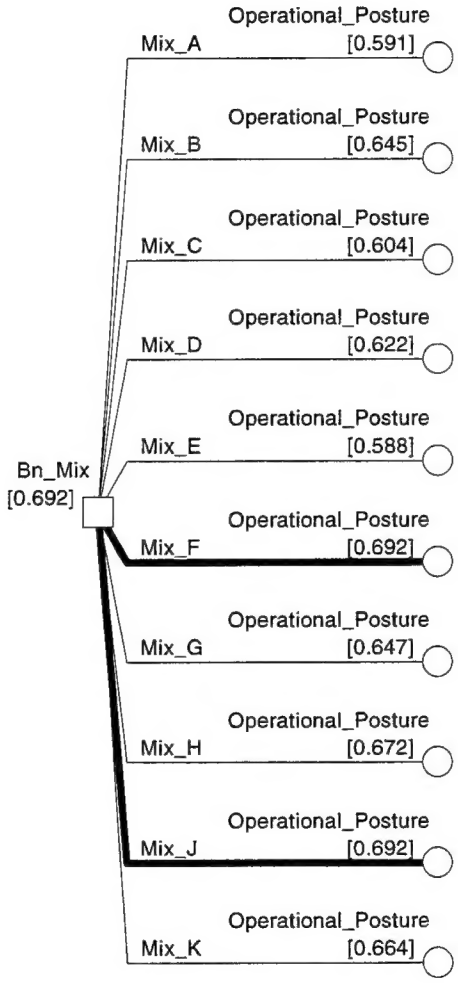
Operational Posture: Offensive 0.3 / Defensive 0.7



Operational Posture: Offensive 0.2 / Defensive 0.8



Operational Posture: Offensive 0.1 / Defensive 0.9



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13. ABSTRACT *(Maximum 200 words)*

This thesis describes the development of a methodology to explicitly model corps artillery assets in the Joint Staff's Joint Stochastic Analysis Research (J-STOCHWAR) and to quantify Army doctrine that guides organization of artillery for combat. The methodology incorporates corps artillery into the J-STOCHWAR by using the five fundamentals for organizing for combat, which reflect Army doctrine, and combines them with basic concepts already used in existing theater-level models. Other aspects of the problem include determining the appropriate level of detail, identifying techniques to solve the problem, and verifying the results.

The proposed decision analysis solution technique provides a feasible method to maximize the utility of organizing artillery for combat based on an operational posture perception provided by the J-STOCHWAR. The influence diagram algorithm incorporates the effects and weights of the five fundamentals involved in the organization process. The methodology provides accurate input to J-STOCHWAR that approximates real world results.

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